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Duane Arnold Energy Center
CEDAR RIVER OPERATIONAL ECOLOGICAL STUDY
ANNUAL REPORT

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INTRODUCTION

This report presents the results of the physical, chemical, and biological studies of the Cedar River in the vicinity of the Duane Arnold Energy Center during the 18th year of station operation (January 1991 to December 1991).

The Duane Arnold Energy Center Operational Study was implemented in mid-January, 1974. Prior to plant start-up extensive preoperational data were collected from April, 1971 to January, 1974. These preoperational studies provided a substantial amount of "baseline" data with which to compare the information collected since the station became operational. The availability of 18 years of operational data, collected under a variety of climatic and hydrological conditions, provides an excellent basis for the assessment of the effects of the operation of the Duane Arnold Energy Center on the limnology and water quality of the Cedar River. Equally important is the availability of sufficient data to identify long-term trends in the water quality of the Cedar River which are unrelated to station operation, but are indicative of climatic patterns, changes in land use practices, or pollution control procedures within the Cedar River basin.

SITE DESCRIPTION

The Duane Arnold Energy Center, a nuclear fueled electrical generating plant, operated by the Iowa Electric Light and Power Company, is located on the west side of the Cedar River, approximately two and one-half miles north-northeast of Palo, Iowa, in Linn County. The plant employs a boiling water nuclear power reactor which produces approximately 560 MWe of power (1650 MWth) at full capacity. Waste heat rejected from the turbine cycle to the condenser circulating water is removed by two closed loop induced draft cooling towers which require a maximum of 11,000 gpm (ca. 24.5 cfs) of water from the Cedar River. A maximum of 7,000 gpm (ca. 15.5 cfs) may be lost through evaporation, while 4,000 gpm (ca. 9 cfs) may be returned to the river as blowdown water from the cool side of the cooling towers.

OBJECTIVES

Studies to determine the baseline physical, chemical, and biological characteristics of the Cedar River near the Duane Arnold Energy Center prior to plant start-up were instituted in April of 1971. These preoperational studies are described in earlier reports.¹⁻³ Data from these studies served as a basis for the development of the operational study.

The operational studies were designed to identify and evaluate any significant effects of chemical or thermal discharges from the generating station into the Cedar River, as well as to assess the magnitude of impingement of the fishery on intake screens or entrainment in the condenser make-up water. These were first implemented in January, 1974 and have continued without interruption through the current year.

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The specific objectives of the operational study are twofold:

1. To continue routine water quality determinations in the Cedar River in order to identify any conditions which could result in environmental or water quality problems.
2. To conduct physical, chemical, and biological studies in and adjacent to the discharge canal and to compare the results with similar studies executed above the intake. This will make possible the determination of any water quality changes occurring as a result of chemical additions or condenser passage, and to identify any impacts of the plant effluent on aquatic communities adjacent to the discharge.

STUDY PLAN

During the operational phase of the study sampling sites were established in the discharge canal and at four locations in the Cedar River (Figure 1): 1) upstream of the plant at the Lewis Access Bridge (Station 1); 2) directly upstream

of the plant intake (Station 2); 3) at a point within the mixing zone approximately 140 feet downstream of the plant discharge (Station 3); and 4) adjacent to Comp Farm, located about one-half mile below the plant (Station 4). Samples were also taken from the discharge canal (Station 5).

Prior to 1979, samples were collected and analyzed by the Department of Environmental Engineering of the University of Iowa. From January, 1979 through December, 1983 samples were collected and analyzed by Ecological Analysts, Inc. Since 1984 collection and analysis of samples has been conducted by the University of Iowa Hygienic Laboratory, located in Iowa City, Iowa. The conclusions contained in this annual report are based on the results of their analyses. Samples for routine physical, chemical, and biological analysis were taken twice per month, while other studies were conducted seasonally. The following are discussed in this report:

I. General Water Quality Analysis

- A. Frequency: twice per month
- B. Location: at all five stations

C. Parameters Measured:

- | | |
|---|---|
| 1. Temperature | 8. Hardness series (total and calcium) |
| 2. Turbidity | 9. Phosphate series (total and ortho) |
| 3. Solids (total, dissolved, and suspended) | 10. Ammonia |
| 4. Dissolved oxygen | 11. Nitrate |
| 5. Carbon dioxide | 12. Iron |
| 6. Alkalinity (total and carbonate) | 13. Biochemical oxygen demand |
| 7. pH | 14. Coliform series (fecal and <u>E. coli</u>) |

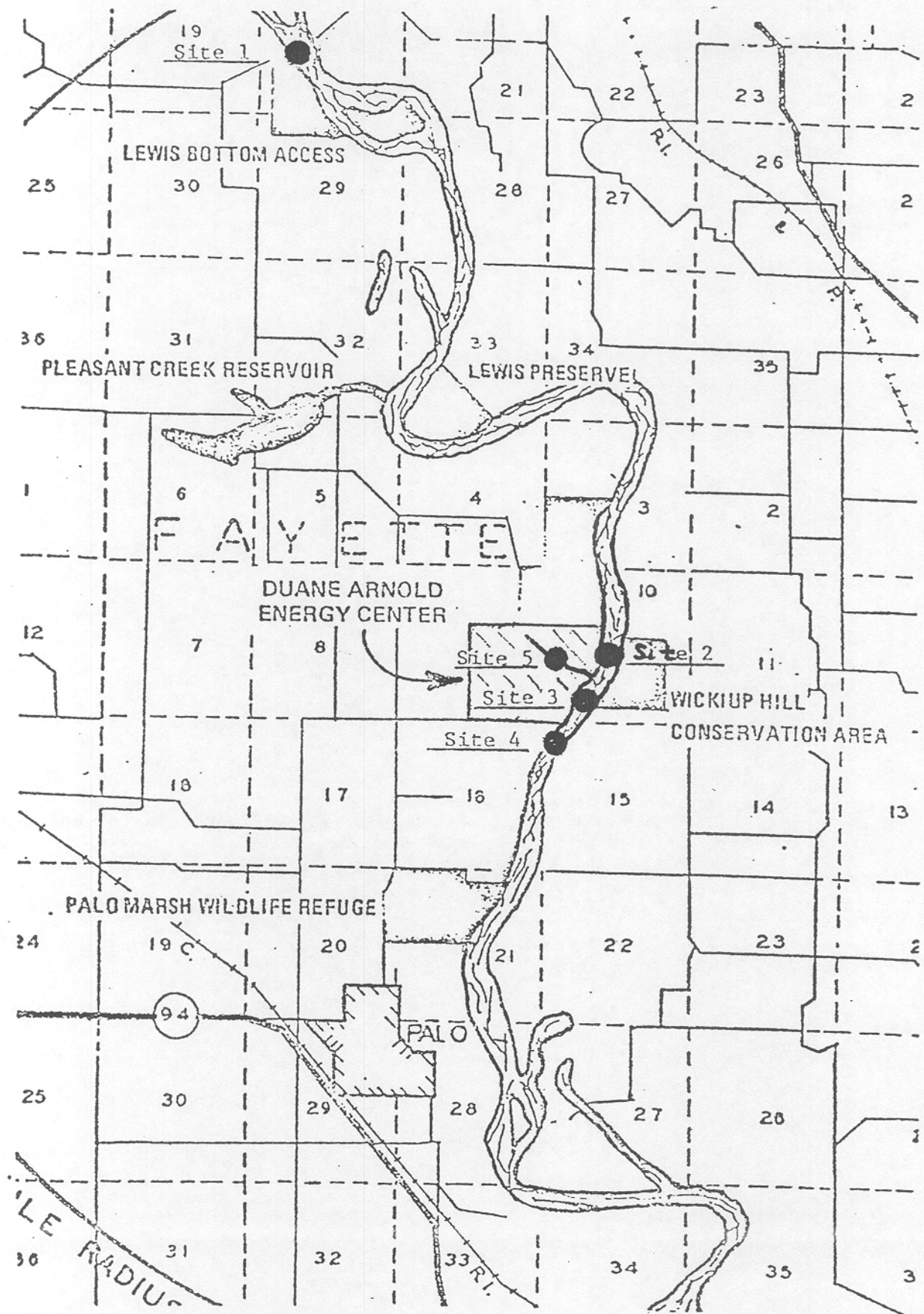


Figure 1. Location of Operational Sampling Sites

II. Additional Chemical Determinations

- A. Frequency: twice yearly
- B. Location: at all five stations
- C. Parameters Measured:

- | | |
|--------------|-------------|
| 1. Chromium | 5. Mercury |
| 2. Copper | 6. Zinc |
| 3. Lead | 7. Chloride |
| 4. Manganese | 8. Sulfate |

III. Biological Studies

A. Benthic Studies:

- 1. Frequency: summer and fall
- 2. Location: at all five stations

B. Asiatic Clam (Corbicula) and Zebra Mussel (Dreissena) Surveys:

- 1. Frequency: twice yearly
- 2. Location: upstream and downstream of the plant, intake bay, cooling tower basin, and discharge canal. The Zebra mussel survey also included Pleasant Creek Reservoir.

C. Impingement Studies:

- 1. Frequency: daily
- 2. Location: intake structure

OBSERVATIONS

Physical Conditions

Hydrology (Table 1)

River flows during 1991 were consistently well above normal. Mean monthly flows ranged from 111% of the median monthly discharge in September to 631% in December. Estimated mean flow for the year was ca. 8,085 cfs, far higher than the 20 year average flow of ca. 4,792 cfs and the second highest mean flow observed during the 20 year study. Mean monthly discharges at the Cedar Rapids gauging station ranged from 1,510 cfs in January to 24,500 cfs in May. Mean monthly discharges in 1991 were classified as excessive (greater than the 75% quartile) from

March through June, and in August, November, and December. Winter flows remained relatively low through late February, ranging from a yearly minimum of 1,080 cfs on February 27 to 4,430 cfs on February 22, and then increased to an early spring high of 25,300 cfs by March 28. Flows remained very high throughout the spring. A yearly high of 45,500 cfs occurred on May 23. Early June flows were also very high but declined steadily throughout the month to 5,600 cfs by June 30. Flows continued to decline through July and early August to 1,750 cfs by August 5, and then increased to 8,700 cfs by mid month. September and October flows were near normal, ranging from 1,360 to 3,010 cfs, but November and December continued well above average. A record high December flow of 17,600 cfs was recorded on December 13. Hydrological data are summarized in Table 1.

Temperature (Table 2)

Ambient upstream river temperatures during 1991 ranged from 0.0°C (32.0°F) to 24.5°C (76.1°F). The maximum ambient (Station 1) temperatures were observed on June 19 and July 11. This value was the lowest since 1984¹⁴ and well below the 1980 to 1991 average maximum of 27°C (81°F). A maximum downstream temperature of 27.0°C (80.6°F) was observed at Station 4 one-half mile below the plant on July 25. The highest discharge canal (Station 5) temperature observed during the period was 29.0°C (84.2°F), which was recorded on July 11 and September 3. A maximum temperature differential (ΔT value) between the upstream river and the discharge canal (Stations 2 vs. Station 5) of 11.5°C (20.7°F) was observed on October 15.

Station operation had little effect on downstream water temperatures. The maximum ΔT value between ambient upstream temperatures at Station 2 and downstream temperatures at Station 3, located in the mixing zone for the discharge canal, of 1.5°C (2.7°F) was measured on October 1. A maximum temperature elevation at the Comp Farm station, one-half mile below the plant (Station 2 vs. Station 4) of 2.5°C (4.5°F) was observed on June 25. There was no instance in which a temperature

elevation in excess of the Iowa water quality standard²¹ of -3°C was observed. No other samples taken at Station 4 exhibited temperature differentials in excess of 1.0°C (1.8°F) above ambient. A summary of water temperature differentials between upstream and downstream locations is given in Table 3.

Turbidity (Table 4)

Average river turbidity values were the highest observed during the 20 year study period, due likely to the very high river flows in 1991. Maximum ambient river levels were also high. Peak values of 380-390 occurred at upstream river locations in early May. Low values (2-4 NTU) occurred during January and early February. In contrast to most previous years, turbidity values in the discharge canal were not higher than those observed in the upstream river. A maximum discharge canal turbidity of 290 NTU was observed on May 1.

Solids (Tables 5-7)

Solids determinations included total, dissolved, and suspended. Total solids values in upstream river samples were higher than those observed in 1990.²⁰ Values ranged from 330 to 640 mg/L, with the majority falling between 400 and 500 mg/L.

Dissolved solids values were similar to those present in 1990. Upstream values ranged from 220 to 560 mg/L. Values of less than 300 mg/L occurred at intervals from mid April through early September. High values continued to occur in the winter. Dissolved solids values at Station 3, 140 feet downstream of the discharge canal, were only slightly higher than values observed upstream, and differences were less obvious than those present in 1989 and 1990. A maximum downstream value of 540 mg/L was observed at Station 3 on February 21.

Suspended solids values at river locations were relatively high in 1991, ranging from <1 to 440 mg/L. Low values occurred in January and early February, while highest values accompanied high flows in early May.

As in previous years, total and dissolved solids values in the discharge canal were higher than in the river samples, but differences were substantially less than those observed in 1990. Maximum total solids concentrations of 1,600 mg/L were observed in the discharge canal in early July, while a minimum of 380 mg/L was observed on February 6.

Chemical Conditions

Dissolved Oxygen (Table 8)

Dissolved oxygen concentrations in river samples collected during 1991 continued to be relatively high, ranging from 6.8 to 16.0 mg/L (80 to 110% saturation). Highest dissolved oxygen concentrations (ca. 12-16 mg/L) continued to occur in the river at intervals from late January to early April, and from mid October through December. Lowest values occurred in May and June in conjunction with high river flow.

Dissolved oxygen concentrations in the discharge canal (Station 5) ranged from 5.4 to 16.0 mg/L (69 to 111% saturation). Lowest values occurred in late August and early September. Highest values were observed in January and December.

Carbon Dioxide (Table 9)

Carbon dioxide concentrations were somewhat higher than those present in 1990,²⁰ ranging from <1 to 7 mg/L. From July through October values were below 1 mg/L. Maximum levels (5-7 mg/L) occurred in January and February.

Alkalinity, pH, Hardness (Tables 10-14)

These interrelated parameters were influenced by a variety of factors, including hydrological, climatic, and biological conditions. Average total alkalinity values in the 1991 river samples were similar to those present in 1990 but higher than those present in 1989.^{20,19} Current values ranged from 88 to 254 mg/L. Lowest values occurred in early May accompanying high river flows. Unlike the drought years of 1988 and 1989, lowest values did not occur during periods of

low flow. Highest values generally occurred during periods of low flow in January, February, and October.

Carbonate alkalinity was not present in river samples from January through June and in November and December. Maximum values of 20 mg/L were observed in late July.

Values for pH in river samples were generally somewhat lower than those observed in 1990, ranging from 7.8 to 8.9. Highest values occurred from late July through October. As in previous years, highest levels accompanied increased photosynthetic activity.

Total hardness values in the upstream river were similar to those present in 1990 and generally paralleled total alkalinity levels. The highest values (360-375 mg/L) occurred during early January, while low values of 170 mg/L occurred during early May.

Hardness values in the discharge canal continued to be consistently higher during periods of station operation than upstream river values; a result of reconcentration in the blowdown. Total hardness levels in the discharge canal ranged from 230 to 975 mg/L. Because of high river flows in 1991, levels downstream of the station were not generally higher than upstream values during periods of station operation.

Phosphates (Tables 15 and 16)

Total phosphate concentrations in upstream river samples increased over 1990²⁰ levels but were generally similar to those observed in 1989.¹⁹ Ambient concentrations in the river ranged from 0.1 to 1.1 mg/L. High levels usually accompanied periods of high stream flow and runoff. Levels in the discharge canal were usually slightly higher than those observed in the river. Discharge canal values ranged from 0.2 to 1.8 mg/L.

Orthophosphate concentrations in river samples were usually less than 0.1 mg/L from early July through October. High values of 0.3 mg/L were present in February

and late May. As in previous years, orthophosphate concentrations were lower than total phosphate levels, and as expected, the greatest differential between phosphate forms coincided with large plankton populations and the resultant uptake of orthophosphate.

Ammonia (Table 17)

Average ammonia concentrations in the river were similar to those observed in 1990²⁰. Concentrations were consistently below detection limits (<0.1 mg/L as N) from April through December. High concentrations of 0.6 to 0.8 mg/L (as N) occurred in February.

Nitrate (Table 18)

In contrast to the low flow years of 1988 and 1989,^{18,19} mean nitrate concentrations continued the pattern present in 1990 and were extremely high in 1991, reaching their highest level since 1983. This was the third highest mean nitrate value observed during the 1972 to 1991 period (Table 27). During the current year nitrate values in upstream river samples ranged from 2.0 to 20 mg/L (as N). Maximum levels (12-20 mg/L as N) occurred from late March through April and in mid May during periods of high river flow. Minimum levels of 2.0 to 3.3 mg/L (as N) occurred during September when flows were low.

In contrast to 1990, nitrate concentrations were not consistently higher in the discharge canal than in river samples. A maximum nitrate concentration of 21 mg/L (as N) was observed in the discharge canal on July 11.

Iron (Table 19)

Iron concentrations in the upstream river remained high during 1991. Concentrations ranged from 0.04 to 5.2 mg/L. The maximum value was observed in early May accompanying high flow and turbidity. Low values of 0.04 mg/L occurred during January when river flow was low. As in previous years, high iron concentrations were usually observed in association with increased turbidity and

suspended solids, indicating that most of the iron present was in the suspended form rather than in solution. In contrast to earlier years, iron levels were not consistently higher in the discharge canal during 1991. A maximum iron value of 3.7 mg/L was observed in the canal in May.

Biological Studies

Biochemical Oxygen Demand (Table 20)

Average five day biochemical oxygen demand (BOD₅) values were slightly lower than those observed in 1990 and substantially lower than those present in 1988 and 1989, averaging 4.3 mg/L in 1991 as compared to 9.6, 10.3, and 4.8 mg/L in 1988, 1989, and 1990, respectively (Table 27). Levels in the river ranged from 1 to 21 mg/L. Highest values occurred during the breakup of ice cover and increasing runoff in February. Lowest values, 1-2 mg/L, occurred in January, June, and December. Relatively high BOD values, ranging from 6 to 8 mg/L, were also observed at intervals from July to mid October and appeared to be related to algal blooms.

Coliform Organisms (Tables 21 and 22)

Coliform determinations included enumeration of both fecal coliforms as well as specific determination of Escherichia coli.

Coliform values were substantially higher than those present in 1990. Maximum upstream fecal coliform and E. coli levels of 22,000 and 15,000 organisms/100 ml, respectively, were observed in early August following a period of rainfall and runoff just prior to sampling. Low values of <10 to 40 organisms/100 ml were observed in October following an extended period of low river flow. In contrast to 1990, fecal coliform and E. coli levels were rarely higher in the discharge canal (Station 5) than at upstream locations. Maximum fecal coliform and E. coli concentrations of 16,000 and 6,500 organisms/100 ml, respectively, were observed in samples from the discharge canal on August 7. These levels were well below those present in the upstream river.

ADDITIONAL STUDIES

In addition to the routine monthly studies a number of seasonal limnological and water quality investigations were conducted during 1991. The studies discussed here include additional chemical determinations, benthic studies, asiatic clam (Corbicula) and zebra mussel (Dreissena) surveys, and impingement determinations.

Additional Chemical Determinations

Samples for additional chemical determinations were collected on April 17 and July 11 and analyzed for chlorides, sulfates, chromium, copper, lead, manganese, mercury, and zinc. In general, concentrations of all parameters in river samples fell within the expected ranges and were similar to those observed during the previous year.

Concentrations of most heavy metals in both the April and July, 1991 samples remained low. With the exception of manganese and zinc, heavy metal values were below detection limits in all river samples. Manganese was present in all river samples at concentrations ranging from 40 to 90 ug/L. Detectable levels of zinc (50 to 70 ug/L) were present in the April river samples, the highest value occurring upstream of the station. No violations of water quality standards for heavy metals were observed.²¹

Reconcentration of solids in the blowdown resulted in substantial increases in sulfate, chloride and manganese in samples from the discharge canal on both sampling dates, but downstream increases were minimal. Relatively high sulfate concentrations were also observed in the discharge canal in April with lesser increases at the downstream locations. The high sulfate levels are due largely to the addition of sulfuric acid for pH control in the cooling water. The results of additional chemical determinations are given in Table 23.

Benthic Studies

Artificial substrate samplers (Hester-Dendy) were placed at each of the four sampling locations upstream and downstream of the station and in the discharge canal on July 7 and September 16, 1991. These substrates were collected on August 22 and October 29, 1991, following a five to six week period to allow for the development of a benthic community.

As in previous years, the communities which developed on the substrates were far larger and more diverse than those which occur on the shifting sand and silt bottom characteristic of the Cedar River in the vicinity of the Duane Arnold Energy Center. A total of 29 taxa were identified during the two sampling periods, 21 in August and 26 in October. These included seven orders of insects, one specie of snail, three species of annelids, and one specie of flatworm. The summer river substrate communities continued to be dominated by trichoptera (caddisfly) larvae while the fall communities were composed primarily of chironomid (midge) and trichoptera larvae. Discharge canal substrates exhibited far fewer organisms and much lower diversity than did river substrates. Trichoptera larvae were also the dominant organisms observed on the discharge canal substrates.

In general, there continued to be little difference in the overall composition of the benthic populations between upstream and downstream locations, although the number of organisms varied considerably.

The total numbers of organisms were substantially higher at the two downstream locations in August while in October largest numbers were present at the upstream (Lewis Access) station. Random differences in the number of organisms at the various locations has been observed during past studies and no consistent pattern has been apparent.

As in previous years, the artificial substrate studies indicate the Cedar River, both upstream and downstream of the Duane Arnold Energy Center, is capable of

supporting a relatively diverse macroinvertebrate fauna in those limited areas where suitable bottom habitat is available. The results of the benthic studies are given in Table 24.

Asiatic Clam and Zebra Mussel Surveys

In past years several power generation facilities have experienced problems with blockage of cooling water intake systems by large numbers of asiatic clams (Corbicula sp.). Although this clam is common in portions of the Iowa reach of the Mississippi River, it is normally absent from areas with shifting sand/silt substrates such as occur in the Cedar River in the vicinity of the Duane Arnold Energy Center. Corbicula has not been collected from the Cedar River in the vicinity of the DAEC during the routine monitoring program, which was implemented in April of 1971. A single Corbicula was, however, collected in January of 1979 in the vicinity of Lewis Access, upstream of DAEC, by Hazelton personnel. Because Corbicula has been collected on one occasion from the Cedar River and is commonly found in power plant intakes on the Mississippi River, studies were implemented at the Duane Arnold Energy Center in 1981 to determine if the organism was present in the vicinity of the station or had established itself within the system. No Corbicula were collected during the 1981 to 1990 investigations.

The zebra mussel (Dreissena polymorpha) is a European form which was first found in the United States in Lake Erie in 1988. It is likely this clam entered the St. Lawrence Seaway from ships that used fresh water from Europe as a ballast and then dumped the water when they reached the United States.²² The mussel has caused major problems in water intakes in Europe for many years and is now causing significant problems at Detroit Edison power plant intakes as well as a number of municipal water treatment plants in the United States. The organisms tend to grow in clumps attached to a solid substrate and can rapidly clog intake structures, screens, and pipes. It is difficult to control chemically and must be removed

mechanically. The mussel is adapted to both river and lake habitats and does especially well in enriched waters which support large plankton populations that it utilizes as food. Unlike the asiatic clam (Corbicula), it is capable of living in cold waters and does not require a silty substrate. Currently this mussel has been found in the Detroit and Illinois Rivers and in Lakes Erie, Michigan, and St. Clair. It has also recently been observed at several locations on the Mississippi River. Although it is impossible to make exact estimates, it will probably continue to increase its range during the next few years. If it does colonize Iowa tributaries to the Mississippi River, problems with intake structures at power plants in the area are likely to occur. As a result of these concerns, studies designed to detect the presence of the Zebra mussel were instituted in 1990. No zebra mussels were found during that year.

In 1991 samples were collected in July and September in the discharge canal and at river locations upstream and downstream of the station, using a mussel rake and/or Ponar dredge and examined for the presence of both the asiatic clam and the zebra mussel. The intake bay, between the bar racks and the traveling screens, and the collection basin of the cooling tower were also sampled. During the July studies the shoreline and littoral area around the discharge structure at Pleasant Creek Lake was also inspected for the presence of the zebra mussel. None of the surveys conducted during 1991 revealed the presence of either species.

Impingement Studies

The total numbers of fish impinged on the intake screens at the Duane Arnold Energy Center during 1991, as reported by Iowa Electric personnel, was the lowest observed during the last three years but still substantially higher than in years prior to 1989. Daily counts conducted by DAEC station personnel indicated a total of 1,415 fish were impinged during 1991. Highest impingement rates continued to occur during the winter and early spring period. During the months of January,

February, and March 1,071 fish, or approximately 76% of the yearly impingement total, were removed from the trash baskets. Lowest impingement rates occurred in June, July, and October when only 15 fish were removed from the trash baskets. The month with the highest impingement rate was February, when 450 fish were collected in the trash baskets. The results of the daily trash basket counts are given in Table 25.

DISCUSSION AND CONCLUSIONS

In contrast to the drought and low river flow which characterized 1988 and 1989, flows in the Cedar River since the spring of 1990 have consistently been above normal. This was especially evident in 1991 when the mean monthly discharge was in excess of the 1951-80 median monthly discharge throughout the entire year, and the mean annual river flow of approximately 8,085 cfs was the highest present since 1983.

Even during the low flow years of 1988 and 1989 the impact of station operation on the water quality of the Cedar River was low, and during the current year, when flows were high, was even less apparent. In 1988 and 1989^{18,19} average temperature differentials (ΔT) during periods of station operation of 1.4 and 1.1°C (2.5 and 2.0°F), respectively, were present between upstream and downstream (Station 2 vs. Station 3) locations as compared to 0.4°C (0.7°F) in 1991. The maximum observed ΔT (Station 2 vs. Station 3) in 1991 was only 1.5°C (2.7°F), well below the 1988 and 1989 maximum differentials of 4.0 and 3.5°C (7.2 and 6.3°F), respectively. Obviously no temperature differentials in excess of the 3°C (5.4°F) water quality standard²¹ were observed during 1991. Other parameters, such as dissolved solids and hardness, which are increased by reconcentration in the blowdown, also exhibited minimal increases at the downstream locations (Table 26).

During 1991 there were no incidents where an exceedence of the applicable Iowa Water quality standards were observed which could be attributed to the operation of

the Duane Arnold Energy Center. On August 7, 1991, high fecal coliform levels were observed at all locations, with the highest values, 37,000 organisms/100 ml, present at Station 3 immediately downstream of the discharge canal. Although fecal coliform levels at this location were nearly twice as high as those observed upstream, they do not appear to constitute a violation of the Iowa Class A water quality standards²¹ since the high levels appear to be related to heavy localized land runoff rather than discharges from the Duane Arnold Energy Center. An additional sample taken on the same date from a drainage ditch southwest of the station exhibited even higher coliform levels of 50,000 organisms/100 ml. These results are not surprising, considering the fact that the drainage ditch receives runoff from agricultural land in the area, and appear to support the hypothesis that the occasional high coliform levels which have been observed in the discharge canal and in the downstream river are the result of localized runoff events rather than activities related to the operation of the Duane Arnold Energy Center.

Although station operation had minimal impact on the water quality of the Cedar River, the effects of the high river flow which characterized 1991 were evident. This was especially true when the results of the current study were compared to those of 1988 and 1989, when flows were well below normal. As expected, sediment related parameters exhibited their highest levels during 1991 when turbidity, suspended solids, iron, and fecal coliform values at the upstream (Station 1) river location averaged 65 NTU, 96 mg/L, 1.03 mg/L, and 1,247 organisms/100 ml, respectively. These compare to 1988 averages of 28 NTU, 63 mg/L, 0.34 mg/L, and 214 organisms/100 ml, and 1989 averages of 24 NTU, 54 mg/L, 0.24 mg/L, and 79 organisms/100 ml. Mean nitrate concentrations in the upstream river were also extremely high, 7.9 mg/L (as N), reaching their highest levels since 1983. In contrast, the mean nitrate values of 2.8 mg/L (as N) present in 1988 was the lowest mean value present since 1976,⁶ and the 1989 mean of 1.5 mg/L (as N) equaled the

second lowest value observed since the inception of the study in 1972 (Table 27). These contrasts are even more apparent when the relative loading values, obtained by multiplying the average annual concentration by annual cumulative runoff, are compared (Table 28).

In contrast, other parameters exhibited substantially lower levels in 1991 than during 1988 or 1989. Average BOD values, which reached peak levels of 9.6 and 10.3 mg/L in 1988 and 1989,^{18,19} respectively, dropped to 4.3 mg/L in 1991 (Table 27). The low BOD values present during the current year resulted from reduced algal production associated with high flow and turbidity in 1991 and the subsequent reduction in the production of autochthonous organic matter by photosynthetic activity. Total hardness values were also higher in 1991 than during 1988 or 1989. The cause of the low total hardness values present in 1988 and 1989 has been discussed in detail in earlier reports²⁰ and appears to be related to the rapid downward movement of surface water through dry unconsolidated surficial deposits into the shallow aquifers feeding the Cedar River. The rapid movement of water during the low flow years shortened its residence time in the surface deposits, reducing the time available for the solubilization of calciferous material.

As expected, the operation of the Duane Arnold Energy Center during 1991 continued to have a minimal impact on the fish and other aquatic organisms in the Cedar River adjacent to the station. The benthic community of the Cedar River in the vicinity of the Duane Arnold Energy Center has been characterized by low diversity and productivity throughout the entire study period. This condition is unrelated to either station operation or poor water quality, but rather to the nature of the river bottom which is characterized by a shifting sand and silt substrate that is not conducive to the development of a diverse or productive benthic community. When artificial substrates (Hester-Dendy) have been placed in the Cedar River, however, they develop populations which are characterized by

relatively high species diversity and many organisms indicative of relatively good water quality. This pattern continued during 1991 when artificial substrates at upstream and downstream locations exhibited generally similar species composition and diversity in both the summer and fall studies. Although the total number of organisms were substantially different between river locations, there appeared to be no consistent pattern present. Total organism numbers were substantially greater at the two downstream locations during the July-August period, but during the September-October study largest numbers were present upstream at the Lewis Access location (Station 1). Random variations in total number of organisms developing on the substrates has been characteristic of past studies.

In contrast, the discharge canal substrates exhibited substantially lower diversity and total numbers on both sampling dates. This pattern was also evident in 1990²⁰ and has been observed at intervals in earlier studies,^{17,18} indicating that the discharge canal provides a less suitable environment for benthic biota. This does not, however, appear to be affecting populations downstream, and the current artificial substrate studies continue to indicate that the operation of the Duane Arnold Energy Center has a minimal impact on the benthic community of the Cedar River.

During 1991 a total of 1,415 fish were impinged on the intake screens at the Duane Arnold Energy Center. This number is slightly lower than the total of 1,981 impinged in 1990, and substantially less than the record number of 4,933 recorded in 1989. The current level is still, however, substantially above numbers observed between 1980 and 1988 when annual impingement rates ranged from 208 to 795.¹⁰⁻¹⁸ Most of the impingement continued to occur during the January-March period when 1,071 fish or approximately 76% of the yearly total were impinged. Increased impingement rates during the winter period appear to be related to the recirculation

of warm water into the intake for deicing purposes, which attracts fish to the area that are subsequently impinged.

Although impingement rates have been somewhat higher in recent years the numbers are still extremely small, considering the size and nature of the fish populations present, and the impact of impingement on the fishery of the Cedar River, is insignificant.

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Table 1
Summary of Hydrological Conditions
Cedar River at Cedar Rapids*
1991

Date	Mean Monthly Discharge cfs	Percent of 1951-1980 Median Discharge
January	1,510	144
February	2,136	175
March	11,060	204**
April	15,290	262**
May	24,500	573**
June	17,030	401**
July	3,078	94
August	3,641	180**
September	1,987	111
October	1,813	121
November	7,054	382**
December	7,918	631**

*Data obtained from U.S. Geological Survey records
 **In excess of the 75% quartile

Table 2

Temperature ($^{\circ}\text{C}$) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

Date 1991	<u>Sampling Locations</u>				
	Upstream of Plant	Upstream of Plant Intake	Discharge Canal	140 Feet Downstream of Discharge	1/2 Mile Downstream from Plant
	1	2	5	3	4
Jan 09	0.0	0.0	0.5	0.0	0.0
Jan 24	0.0	0.0	0.5	1.0	0.0
Feb 06	0.0	0.0	1.0	0.0	1.0
Feb 21	1.0	1.0	7.0	1.5	1.5
Mar 07	1.0	1.0	1.5	1.5	1.5
Mar 20	6.0	5.0	8.0	5.0	5.0
Apr 04	11.0	10.5	13.0	10.5	10.5
Apr 17	10.0	9.0	10.0	9.0	9.0
May 01	13.5	13.0	14.0	14.0	13.5
May 16	20.5	20.5	18.0	20.5	20.5
Jun 05	21.0	20.5	18.0	20.5	20.0
Jun 19	24.5	24.0	23.0	24.0	23.5
Jul 11	24.5	25.5	29.0	25.0	25.0
Jul 25	24.0	24.5	26.5	25.0	27.0
Aug 07	22.0	21.5	22.0	21.5	21.0
Aug 21	21.5	22.0	27.0	22.0	22.5
Sep 03	24.0	24.0	29.0	24.0	24.0
Sep 18	16.0	16.5	17.0	17.0	17.5
Oct 01	13.5	14.0	19.0	15.5	15.0
Oct 15	7.0	7.0	18.5	9.0	9.0
Nov 07	0.0	0.0	4.5	0.0	0.0
Nov 21	5.5	6.0	13.5	6.5	6.5
Dec 04	0.5	1.0	1.5	2.0	1.0
Dec 18	0.0	0.5	0.5	0.5	1.0

Table 3

Summary of Water Temperature Differentials
and Station Output During Periods of
Cedar River Sampling in 1991

Date	ΔT ($^{\circ}\text{C}$) Upstream River (Sta. 2) vs. Discharge. (Sta. 5)	ΔT ($^{\circ}\text{C}$) Upstream River (Sta. 2) vs. Downstream River (Sta. 3)	ΔT ($^{\circ}\text{C}$) Upstream River (Sta. 2) vs. Downstream River (Sta. 4)	Station Output (% Full Power)
Jan 09	0.5	0.0	0.0	76
Jan 24	0.5	-0.5	0.5	96
Feb 06	1.0	0.0	1.0	98
Feb 21	6.0	0.5	0.5	95
Mar 07	0.5	0.0	0.0	95
Mar 20	3.0	0.0	0.0	96
Apr 04	2.5	0.0	0.0	96
Apr 17	1.0	0.0	0.0	99
May 01	1.0	1.0	0.5	96
May 16	-1.5	0.0	0.0	93
Jun 05	-1.5	0.0	-0.5	93
Jun 19	-1.0	0.0	-0.5	92
Jul 11	3.5	-0.5	-0.5	96
Jul 25	2.0	0.5	2.5	97
Aug 07	0.5	0.0	-0.5	95
Aug 21	5.0	0.0	0.5	96
Sep 03	5.0	0.0	0.5	96
Sep 18	0.5	0.5	1.0	98
Oct 01	5.0	1.5	1.0	97
Oct 15	11.5	0.5	1.0	99
Nov 07	4.5	0.0	0.0	96
Nov 21	7.5	0.5	0.5	99
Dec 04	0.5	1.0	0.0	99
Dec 18	0.0	0.0	0.5	95

Table 4

Turbidity (NTU) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

Date 1991	<u>Sampling Locations</u>				
	<u>Upstream of Plant</u> 1	<u>Upstream of Plant Intake</u> 2	<u>Discharge Canal</u> 5	<u>140 Feet Downstream of Discharge</u> 3	<u>1/2 Mile Downstream from Plant</u> 4
Jan 09	2	2	8	2	2
Jan 24	2	3	4	6	4
Feb 06	4	3	14	3	3
Feb 21	140	110	21	78	38
Mar 07	49	51	54	54	53
Mar 20	200	180	95	200	200
Apr 04	34	41	20	39	39
Apr 17	67	68	36	72	71
May 01	380	390	290	420	400
May 16	88	93	44	90	94
Jun 05	120	130	57	140	140
Jun 19	95	110	65	110	110
Jul 11	28	29	74	28	26
Jul 25	33	38	96	42	39
Aug 07	56	83	150	150	92
Aug 21	43	44	92	48	42
Sep 03	31	33	64	36	38
Sep 18	45	46	69	50	49
Oct 01	15	14	150	13	13
Oct 15	13	14	33	18	16
Nov 07	32	34	27	37	35
Nov 21	46	44	24	42	46
Dec 04	16	17	18	17	15
Dec 18	29	29	24	30	30

Table 5

Total Solids (mg/L) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

Date 1991	<u>Sampling Locations</u>				
	<u>Upstream of Plant</u> 1	<u>Upstream of Plant Intake</u> 2	<u>Discharge Canal</u> 5	<u>140 Feet Downstream of Discharge</u> 3	<u>1/2 Mile Downstream from Plant</u> 4
Jan 09	390	400	520	400	400
Jan 24	400	380	410	390	390
Feb 06	410	410	380	420	430
Feb 21	560	550	600	540	330
Mar 07	450	440	460	430	440
Mar 20	540	550	1100	580	570
Apr 04	450	400	1200	450	440
Apr 17	410	400	970	410	400
May 01	600	640	530	670	660
May 16	530	500	1100	520	520
Jun 05	450	470	890	470	460
Jun 19	480	460	1100	490	480
Jul 11	390	370	1600	420	390
Jul 25	410	400	1500	490	450
Aug 07	400	440	450	520	420
Aug 21	450	450	1500	480	480
Sep 03	340	330	1300	400	380
Sep 18	410	420	470	430	430
Oct 01	410	410	1500	600	430
Oct 15	370	370	1100	560	440
Nov 07	400	410	1200	410	410
Nov 21	450	460	480	460	470
Dec 04	460	470	470	490	490
Dec 18	400	400	410	400	400

Table 6

Dissolved Solids (mg/L) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

<u>Date</u> <u>1991</u>	<u>Upstream</u> <u>of Plant</u> 1	<u>Upstream</u> <u>of Plant</u> <u>Intake</u> 2	<u>Sampling Locations</u>		
			<u>Discharge</u> <u>Canal</u> 5	<u>140 Feet</u> <u>Downstream</u> <u>of Discharge</u> 3	<u>1/2 Mile</u> <u>Downstream</u> <u>from Plant</u> 4
Jan 09	390	390	500	390	400
Jan 24	370	380	380	380	370
Feb 06	380	380	330	390	410
Feb 21	560	550	600	540	330
Mar 07	310	320	340	320	310
Mar 20	320	220	920	240	230
Apr 04	360	350	1100	360	350
Apr 17	280	270	850	300	260
May 01	260	270	130	220	200
May 16	340	350	980	330	340
Jun 05	290	280	760	280	270
Jun 19	320	290	930	310	300
Jul 11	270	280	1300	320	300
Jul 25	300	290	1200	340	330
Aug 07	260	260	270	270	240
Aug 21	330	320	1300	360	340
Sep 03	240	240	1100	280	280
Sep 18	300	300	310	310	300
Oct 01	320	330	1100	510	370
Oct 15	*	300	970	460	350
Nov 07	320	330	1000	330	330
Nov 21	320	340	410	340	330
Dec 04	380	380	400	390	400
Dec 18	330	340	360	340	330

* Laboratory accident

Table 7

Suspended Solids (mg/L) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

Date 1991	<u>Sampling Locations</u>				
	<u>Upstream of Plant</u> 1	<u>Upstream of Plant Intake</u> 2	<u>Discharge Canal</u> 5	<u>140 Feet Downstream of Discharge</u> 3	<u>1/2 Mile Downstream from Plant</u> 4
Jan 09	<1	1	11	2	3
Jan 24	4	4	6	12	8
Feb 06	1	3	28	3	3
Feb 21	290	200	29	170	77
Mar 07	93	90	84	98	88
Mar 20	260	290	84	310	300
Apr 04	66	75	19	70	69
Apr 17	79	85	38	85	85
May 01	370	400	270	440	440
May 16	140	130	44	130	140
Jun 05	140	150	52	160	150
Jun 19	130	140	48	150	150
Jul 11	74	65	130	72	66
Jul 25	64	70	180	90	88
Aug 07	110	160	160	240	160
Aug 21	76	86	140	86	88
Sep 03	66	67	110	72	75
Sep 18	84	94	140	98	100
Oct 01	32	34	370	46	28
Oct 15	30	34	64	36	36
Nov 07	40	43	33	47	46
Nov 21	88	86	20	80	86
Dec 04	24	25	29	28	23
Dec 18	35	37	17	38	40

Table 8

Dissolved Oxygen (mg/L) Values from the Cedar River Near
the Duane Arnold Energy Center in 1991

Date 1991	<u>Sampling Locations</u>				
	<u>Upstream of Plant</u>	<u>Upstream of Plant Intake</u>	<u>Discharge Canal</u>	<u>140 Feet Downstream of Discharge</u>	<u>1/2 Mile Downstream from Plant</u>
	1	2	5	3	4
Jan 09	11.8	11.6	12.0	11.6	12.2
Jan 24	13.2	13.3	15.3	13.2	12.5
Feb 06	11.4	11.0	12.2	10.8	10.6
Feb 21	11.7	11.9	12.2	11.4	11.1
Mar 07	12.6	12.0	12.6	11.8	12.2
Mar 20	12.0	13.4	10.9	13.4	12.4
Apr 04	10.5	10.1	12.6	10.2	10.2
Apr 17	10.0	10.2	7.0	10.3	10.2
May 01	9.1	9.0	9.3	8.6	8.4
May 16	8.5	8.3	6.7	8.2	8.2
Jun 05	8.5	8.1	7.6	7.6	7.7
Jun 19	7.1	6.8	7.4	7.0	7.1
Jul 11	10.7	11.4	6.6	11.3	12.3
Jul 25	10.2	11.1	7.5	11.8	12.4
Aug 07	9.3	8.3	7.4	8.0	8.2
Aug 21	9.4	9.7	6.2	9.6	11.2
Sep 03	8.8	8.0	5.4	9.0	9.2
Sep 18	10.4	9.8	8.6	10.6	10.8
Oct 01	11.2	11.8	7.7	11.8	12.8
Oct 15	12.8	13.6	8.3	13.0	15.4
Nov 07	13.9	14.0	8.6	14.0	16.0
Nov 21	12.2	11.5	7.6	10.6	11.5
Dec 04	13.0	12.5	12.7	12.5	14.7
Dec 18	14.0	15.0	16.0	15.7	14.6

Table 9

Carbon Dioxide (mg/L) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

Date 1991	<u>Sampling Locations</u>				
	<u>Upstream of Plant</u> 1	<u>Upstream of Plant Intake</u> 2	<u>Discharge Canal</u> 5	<u>140 Feet Downstream of Discharge</u> 3	<u>1/2 Mile Downstream from Plant</u> 4
Jan 09	7	7	4	7	7
Jan 24	5	4	4	5	5
Feb 06	6	6	3	6	5
Feb 21	4	6	2	6	5
Mar 07	3	2	2	3	3
Mar 20	2	2	*	2	3
Apr 04	2	2	*	2	2
Apr 17	3	3	*	3	3
May 01	2	2	2	2	3
May 16	2	3	5	3	2
Jun 05	3	2	11	3	3
Jun 19	2	2	*	3	3
Jul 11	<1	<1	*	<1	<1
Jul 25	<1	<1	*	<1	<1
Aug 07	<1	1	1	1	1
Aug 21	<1	<1	*	<1	<1
Sep 03	<1	<1	*	<1	<1
Sep 18	<1	<1	<1	<1	<1
Oct 01	<1	<1	*	<1	<1
Oct 15	<1	<1	*	<1	<1
Nov 07	3	3	*	3	3
Nov 21	3	3	6	3	3
Dec 04	3	3	3	3	3
Dec 18	5	3	4	4	4

*Unable to calculate

Table 10

Total Alkalinity (mg/L - CaCO_3) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

<u>Date</u> <u>1991</u>	<u>Sampling Locations</u>				
	<u>Upstream</u> <u>of Plant</u> 1	<u>Upstream</u> <u>of Plant</u> <u>Intake</u> 2	<u>Discharge</u> <u>Canal</u> 5	<u>140 Feet</u> <u>Downstream</u> <u>of Discharge</u> 3	<u>1/2 Mile</u> <u>Downstream</u> <u>from Plant</u> 4
Jan 09	238	254	134	246	244
Jan 24	244	242	232	240	240
Feb 06	232	236	150	226	226
Feb 21	134	184	74	190	192
Mar 07	162	176	174	178	170
Mar 20	138	138	172	132	150
Apr 04	202	202	210	196	190
Apr 17	126	146	234	136	140
May 01	110	96	92	90	88
May 16	182	194	230	206	178
Jun 05	164	166	224	158	168
Jun 19	164	154	182	164	182
Jul 11	172	168	120	170	168
Jul 25	206	194	128	196	176
Aug 07	156	152	90	106	134
Aug 21	214	210	146	206	198
Sep 03	140	140	112	142	196
Sep 18	188	190	198	198	208
Oct 01	244	216	164	200	216
Oct 15	194	190	118	176	196
Nov 07	200	196	232	214	214
Nov 21	216	210	204	222	218
Dec 04	234	224	226	242	250
Dec 18	206	184	190	200	190

Table 11

Carbonate Alkalinity (mg/L - CaCO_3) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

Date 1991	<u>Sampling Locations</u>				
	<u>Upstream of Plant</u> 1	<u>Upstream of Plant Intake</u> 2	<u>Discharge Canal</u> 5	<u>140 Feet Downstream of Discharge</u> 3	<u>1/2 Mile Downstream from Plant</u> 4
Jan 09	<1	<1	<1	<1	<1
Jan 24	<1	<1	<1	<1	<1
Feb 06	<1	<1	<1	<1	<1
Feb 21	<1	<1	<1	<1	<1
Mar 07	<1	<1	<1	<1	<1
Mar 20	<1	<1	<1	<1	<1
Apr 04	<1	<1	<1	<1	<1
Apr 17	<1	<1	<1	<1	<1
May 01	<1	<1	<1	<1	<1
May 16	<1	<1	<1	<1	<1
Jun 05	<1	<1	<1	<1	<1
Jun 19	<1	<1	<1	<1	<1
Jul 11	2	4	<1	4	4
Jul 25	18	16	<1	20	12
Aug 07	8	<1	<1	<1	<1
Aug 21	14	14	<1	14	8
Sep 03	8	6	<1	8	6
Sep 18	10	12	12	14	18
Oct 03	12	10	<1	10	14
Oct 15	10	12	<1	14	20
Nov 07	<1	<1	<1	<1	<1
Nov 21	<1	<1	<1	<1	<1
Dec 04	<1	<1	<1	<1	<1
Dec 18	<1	<1	<1	<1	<1

Table 12

Units of pH from the Cedar River Near the
Duane Arnold Energy Center During 1991

Date 1991	<u>Sampling Locations</u>				
	Upstream of Plant 1	Upstream of Plant Intake 2	Discharge Canal 5	140 Feet Downstream of Discharge 3	1/2 Mile Downstream from Plant 4
Jan 09	8.0	8.0	8.0	8.0	8.0
Jan 24	8.1	8.0	8.2	8.1	8.1
Feb 06	8.0	8.0	8.1	8.0	8.1
Feb 21	8.0	8.0	8.0	8.0	8.1
Mar 07	8.2	8.3	8.3	8.3	8.2
Mar 20	8.2	8.2	7.7	8.2	8.1
Apr 04	8.3	8.3	7.7	8.3	8.3
Apr 17	8.0	8.1	7.8	8.1	8.1
May 01	8.0	7.9	8.0	7.9	7.8
May 16	8.1	8.1	7.9	8.1	8.1
Jun 05	8.0	8.1	7.6	8.0	8.0
Jun 19	8.2	8.1	7.5	8.0	8.1
Jul 11	8.4	8.4	8.0	8.5	8.7
Jul 25	8.7	8.7	8.0	8.7	8.7
Aug 07	8.5	8.3	8.3	8.2	8.2
Aug 21	8.6	8.6	8.0	8.6	8.6
Sep 03	8.6	8.4	7.7	8.6	8.4
Sep 18	8.7	8.7	8.6	8.7	8.7
Oct 01	8.7	8.7	8.0	8.7	8.8
Oct 15	8.7	8.8	8.0	8.6	8.9
Nov 07	8.3	8.3	7.4	8.3	8.3
Nov 21	8.2	8.3	7.9	8.3	8.3
Dec 04	8.3	8.3	8.3	8.3	8.3
Dec 18	8.1	8.2	8.2	8.2	8.2

Table 13

Total Hardness (mg/L - CaCO_3) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

Date 1991	<u>Sampling Locations</u>				
	<u>Upstream of Plant</u>	<u>Upstream of Plant Intake</u>	<u>Discharge Canal</u>	<u>140 Feet Downstream of Discharge</u>	<u>1/2 Mile Downstream from Plant</u>
	1	2	5	3	4
Jan 09	360	355	405	375	350
Jan 24	310	315	330	310	320
Feb 06	290	320	250	305	320
Feb 21	192	235	375	260	265
Mar 07	250	265	290	245	260
Mar 20	210	215	675	218	220
Apr 04	325	325	785	315	320
Apr 17	260	260	655	275	255
May 01	190	175	285	170	210
May 16	280	285	705	295	285
Jun 05	250	245	570	240	250
Jun 19	295	270	740	275	295
Jul 11	250	250	890	280	280
Jul 25	270	262	865	305	290
Aug 07	230	250	230	225	220
Aug 21	292	298	975	316	328
Sep 03	215	210	765	245	245
Sep 18	250	252	275	258	250
Oct 01	312	292	795	405	315
Oct 15	255	250	690	378	300
Nov 07	245	295	715	290	265
Nov 21	295	300	335	300	310
Dec 04	320	325	340	340	340
Dec 18	280	270	300	300	290

Table 14

Calcium Hardness (mg/L - CaCO_3) from the Cedar River Near
the Duane Arnold Energy Center During 1991

Date 1991	<u>Sampling Locations</u>				
	<u>Upstream of Plant</u> 1	<u>Upstream of Plant Intake</u> 2	<u>Discharge Canal</u> 5	<u>140 Feet Downstream of Discharge</u> 3	<u>1/2 Mile Downstream from Plant</u> 4
Jan 09	220	225	260	225	230
Jan 24	220	230	215	230	220
Feb 06	210	210	175	215	225
Feb 21	138	165	266	175	185
Mar 07	180	185	180	175	175
Mar 20	150	150	471	158	155
Apr 04	200	255	571	240	205
Apr 17	160	160	460	195	165
May 01	125	125	125	140	120
May 16	190	190	494	190	185
Jun 05	160	160	406	115	160
Jun 19	185	175	475	190	175
Jul 11	150	145	530	165	165
Jul 25	185	180	551	195	185
Aug 07	140	130	120	140	140
Aug 21	190	180	600	200	200
Sep 03	120	120	406	120	125
Sep 18	140	150	160	160	130
Oct 01	190	180	511	260	200
Oct 15	160	165	416	228	180
Nov 07	190	185	480	195	180
Nov 21	205	210	235	210	210
Dec 04	220	215	235	235	225
Dec 18	190	210	205	180	195

Table 15

Total Phosphorus (mg/L-P) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

Date 1991	<u>Sampling Locations</u>				
	<u>Upstream of Plant</u>	<u>Upstream of Plant Intake</u>	<u>Discharge Canal</u>	<u>140 Feet Downstream of Discharge</u>	<u>1/2 Mile Downstream from Plant</u>
	1	2	5	3	4
Jan 09	0.2	0.2	0.7	0.2	0.2
Jan 24	0.3	0.3	0.3	0.3	0.3
Feb 06	0.3	0.3	0.4	0.3	0.4
Feb 21	0.8	0.6	0.7	0.6	0.5
Mar 07	0.4	0.4	0.4	0.4	0.4
Mar 20	0.6	0.6	0.8	0.6	0.6
Apr 04	0.2	0.2	0.4	0.2	0.2
Apr 17	0.3	0.3	0.4	0.3	0.3
May 01	0.9	1.0	0.8	1.0	1.0
May 16	0.4	0.4	0.5	0.4	0.4
Jun 05	1.0	1.1	0.6	0.8	1.0
Jun 19	0.6	0.6	0.9	0.3	0.7
Jul 11	0.3	0.1	1.5	0.2	0.2
Jul 25	0.2	0.3	1.8	0.4	0.3
Aug 07	0.2	0.2	0.2	0.4	0.3
Aug 21	0.3	0.3	1.2	0.3	0.3
Sep 03	0.2	0.2	1.1	0.3	0.2
Sep 18	0.3	0.2	1.7	0.2	0.2
Oct 01	0.2	0.3	1.6	0.5	0.3
Oct 15	0.3	0.2	0.8	0.3	0.2
Nov 07	0.3	0.3	0.8	0.3	0.2
Nov 21	0.5	0.5	0.5	0.4	0.4
Dec 04	0.5	0.5	0.6	0.5	0.4
Dec 18	0.2	1.0	1.2	1.3	1.0

Table 16

Soluble Orthophosphate (mg/L-P) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

Date 1991	<u>Sampling Locations</u>				
	<u>Upstream of Plant</u> 1	<u>Upstream of Plant Intake</u> 2	<u>Discharge Canal</u> 5	<u>140 Feet Downstream of Discharge</u> 3	<u>1/2 Mile Downstream from Plant</u> 4
Jan 09	0.2	0.2	0.4	0.2	0.2
Jan 24	0.2	0.2	0.2	0.2	0.2
Feb 06	0.3	0.3	0.3	0.3	0.3
Feb 21	0.3	0.3	0.3	0.3	0.2
Mar 07	0.2	0.2	0.2	0.2	0.2
Mar 20	0.2	0.2	0.4	0.2	0.2
Apr 04	0.1	0.1	0.2	0.1	0.1
Apr 17	0.1	0.2	0.2	0.2	0.2
May 01	0.2	0.2	0.2	0.2	0.2
May 16	0.3	0.3	0.3	0.2	0.2
Jun 05	0.2	0.2	0.4	0.2	0.2
Jun 19	0.2	0.2	0.4	0.2	0.2
Jul 11	0.1	0.1	0.6	0.2	0.2
Jul 25	<0.1	<0.1	0.5	<0.1	<0.1
Aug 07	<0.1	<0.1	0.2	0.1	<0.1
Aug 21	0.1	0.2	0.3	0.2	0.3
Sep 03	0.1	<0.1	0.2	<0.1	<0.1
Sep 18	<0.1	<0.1	0.1	0.2	0.2
Oct 01	0.1	0.1	0.7	0.2	0.2
Oct 15	<0.1	<0.1	0.5	0.1	0.2
Nov 07	0.1	0.2	0.5	0.2	0.2
Nov 21	0.3	0.2	0.2	0.1	0.1
Dec 04	0.2	0.1	0.1	0.1	0.1
Dec 18	0.1	0.2	0.2	0.2	0.2

Table 17

Ammonia (mg/L-N) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

Date 1991	<u>Sampling Locations</u>				
	<u>Upstream of Plant</u> 1	<u>Upstream of Plant Intake</u> 2	<u>Discharge Canal</u> 5	<u>140 Feet Downstream of Discharge</u> 3	<u>1/2 Mile Downstream from Plant</u> 4
Jan 09	0.4	0.4	0.3	0.4	0.4
Jan 24	0.4	0.4	0.4	0.4	0.4
Feb 06	0.5	0.6	0.5	0.6	0.6
Feb 21	0.8	0.7	0.2	0.7	0.6
Mar 07	0.4	0.4	0.4	0.4	0.4
Mar 20	0.3	0.3	0.1	0.3	0.3
Apr 04	<0.1	<0.1	0.1	<0.1	<0.1
Apr 17	<0.1	<0.1	<0.1	<0.1	<0.1
May 01	<0.1	<0.1	<0.1	<0.1	<0.1
May 16	<0.1	<0.1	0.3	<0.1	<0.1
Jun 05	<0.1	<0.1	0.3	<0.1	0.1
Jun 19	<0.1	<0.1	0.2	<0.1	<0.1
Jul 11	<0.1	<0.1	<0.1	<0.1	<0.1
Jul 25	0.1	0.2	0.2	<0.1	<0.1
Aug 07	<0.1	<0.1	0.1	<0.1	<0.1
Aug 21	<0.1	<0.1	<0.1	<0.1	<0.1
Sep 03	<0.1	<0.1	0.1	<0.1	<0.1
Sep 18	<0.1	<0.1	0.1	0.2	0.2
Oct 01	<0.1	<0.1	0.4	<0.1	<0.1
Oct 15	<0.1	<0.1	<0.1	<0.1	<0.1
Nov 07	0.2	0.1	0.6	0.1	0.1
Nov 21	<0.1	<0.1	0.3	<0.1	<0.1
Dec 04	0.1	0.1	0.1	0.1	0.1
Dec 18	0.1	0.2	0.2	<0.1	0.1

Table 18

Nitrate (mg/L-N) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

Date 1991	<u>Sampling Locations</u>				
	<u>Upstream of Plant</u> 1	<u>Upstream of Plant Intake</u> 2	<u>Discharge Canal</u> 5	<u>140 Feet Downstream of Discharge</u> 3	<u>1/2 Mile Downstream from Plant</u> 4
Jan 09	7.0	6.9	5.6	7.0	7.2
Jan 24	6.5	6.5	6.6	6.5	6.8
Feb 06	6.0	6.0	4.5	6.1	6.3
Feb 21	4.1	4.9	6.3	5.4	5.6
Mar 07	8.0	8.0	8.5	8.1	8.2
Mar 20	20.0	10.0	16.0	10.0	10.0
Apr 04	13.0	12.0	16.0	13.0	13.0
Apr 17	13.0	13.0	8.3	13.0	13.0
May 01	7.8	7.6	7.9	7.7	7.6
May 16	12.0	12.0	8.7	11.0	11.0
Jun 05	9.3	9.1	6.3	9.1	9.0
Jun 19	10.0	10.0	12.0	10.0	10.0
Jul 11	6.1	6.1	21.0	6.6	6.3
Jul 25	5.0	5.0	15.0	5.6	5.2
Aug 07	3.7	3.6	2.5	3.4	3.3
Aug 21	4.9	4.8	13.0	5.0	4.9
Sep 03	2.0	2.0	7.0	2.2	2.2
Sep 18	3.3	3.3	3.2	3.2	3.3
Oct 01	4.6	4.6	11.0	6.1	4.9
Oct 15	4.0	3.9	9.0	5.2	4.3
Nov 07	9.6	9.5	8.3	9.6	9.6
Nov 21	9.5	9.4	9.6	9.5	9.4
Dec 04	10.0	10.0	10.0	10.0	10.0
Dec 18	11.0	11.0	11.0	11.0	11.0

Table 19

Total Iron (mg/L) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

<u>Date</u> <u>1991</u>	<u>Sampling Locations</u>				
	<u>Upstream</u> <u>of Plant</u>	<u>Upstream</u> <u>of Plant</u> <u>Intake</u>	<u>Discharge</u> <u>Canal</u>	<u>140 Feet</u> <u>Downstream</u> <u>of Discharge</u>	<u>1/2 Mile</u> <u>Downstream</u> <u>from Plant</u>
	1	2	5	3	4
Jan 09	0.04	0.04	0.27	0.04	<0.02
Jan 24	0.06	0.08	0.16	0.13	0.13
Feb 06	0.09	0.09	0.30	0.12	0.10
Feb 21	2.4	1.6	0.38	1.4	0.60
Mar 07	1.1	1.2	1.2	1.1	1.2
Mar 20	3.6	3.8	2.1	4.2	3.9
Apr 04	0.77	0.72	0.43	0.68	0.75
Apr 17	2.6	3.2	1.5	2.8	2.7
May 01	4.7	5.2	3.7	5.1	5.5
May 16	0.89	0.92	0.73	0.91	0.92
Jun 05	1.2	1.3	0.77	1.4	1.3
Jun 19	1.4	1.5	1.2	1.5	1.6
Jul 11	0.68	0.65	1.6	0.64	0.60
Jul 25	0.48	0.47	1.8	0.81	0.64
Aug 07	0.68	1.1	1.1	1.7	1.2
Aug 21	0.54	0.54	1.7	0.58	0.63
Sep 03	0.10	0.13	0.61	0.20	0.19
Sep 18	0.66	0.54	0.91	0.59	0.58
Oct 01	0.20	0.15	1.9	0.40	0.20
Oct 15	0.21	0.18	0.52	0.19	0.13
Nov 07	0.50	0.53	0.93	0.61	0.61
Nov 21	0.94	0.96	0.52	1.1	0.93
Dec 04	0.31	0.32	0.39	0.35	0.34
Dec 18	0.46	0.52	0.34	0.46	0.48

Table 20

Biochemical Oxygen Demand (5-day in mg/L) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

<u>Date</u> <u>1991</u>	<u>Sampling Locations</u>				
	<u>Upstream</u> <u>of Plant</u> 1	<u>Upstream</u> <u>of Plant</u> <u>Intake</u> 2	<u>Discharge</u> <u>Canal</u> 5	<u>140 Feet</u> <u>Downstream</u> <u>of Discharge</u> 3	<u>1/2 Mile</u> <u>Downstream</u> <u>from Plant</u> 4
Jan 09	2	2	4	2	2
Jan 24	1	1	1	2	2
Feb 06	2	3	4	2	2
Feb 21	21	14	3	13	8
Mar 07	4	5	5	4	5
Mar 20	4	4	2	4	4
Apr 04	3	3	3	2	2
Apr 17	2	2	2	2	2
May 01	3	3	3	3	3
May 16	3	3	2	3	3
Jun 05	1	1	1	1	1
Jun 19	2	2	2	2	2
Jul 11	6	7	8	7	7
Jul 25	4	6	8	6	6
Aug 07	8	7	5	6	6
Aug 21	5	6	7	6	6
Sep 03	8	8	12	8	8
Sep 18	4	5	6	5	5
Oct 01	5	5	13	6	6
Oct 15	7	7	11	8	8
Nov 07	3	3	1	2	2
Nov 21	2	2	2	2	2
Dec 04	2	2	2	1	2
Dec 18	2	2	2	2	2

Table 21

Coliform Bacteria (Fecal Organisms/100 ml) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

Date 1991	<u>Sampling Locations</u>				
	<u>Upstream of Plant</u> 1	<u>Upstream of Plant Intake</u> 2	<u>Discharge Canal</u> 5	<u>140 Feet Downstream of Discharge</u> 3	<u>1/2 Mile Downstream from Plant</u> 4
Jan 09	880	1,100	3,500	1,000	970
Jan 24	530	460	340	450	200
Feb 06	370	430	30	310	290
Feb 21	330	290	10	180	170
Mar 07	660	580	680	440	570
Mar 20	670	670	440	890	780
Apr 04	690	500	80	620	380
Apr 17	1,200	1,400	380	1,100	1,200
May 01	1,400	1,700	1,100	1,600	1,600
May 16	1,600	1,300	3,600	1,200	1,200
Jun 05	770	600	490	630	720
Jun 19	1,000	790	690	900	920
Jul 11	140	40	200	170	150
Jul 25	250	150	5,700	250	150
Aug 07	14,000	22,000	16,000	37,000	6,000
Aug 21	220	350	700	280	390
Sep 03	30	70	*	300	200
Sep 18	920	760	1,800	1,000	960
Oct 01	70	50	900	110	50
Oct 15	40	<10	150	30	70
Nov 07	2,500	2,500	1,400	2,500	1,400
Nov 21	1,800	1,900	1,200	1,500	1,700
Dec 04	470	470	340	570	470
Dec 18	380	410	380	360	380

*Unable to determine

Table 22

Coliform Bacteria (*E. coli*/100 ml) Values from the Cedar River Near
the Duane Arnold Energy Center During 1991

Date 1991	<u>Sampling Locations</u>				
	<u>Upstream of Plant</u> 1	<u>Upstream of Plant Intake</u> 2	<u>Discharge Canal</u> 5	<u>140 Feet Downstream of Discharge</u> 3	<u>1/2 Mile Downstream from Plant</u> 4
Jan 09	650	860	3,400	960	980
Jan 24	270	270	70	150	60
Feb 06	170	260	10	200	160
Feb 21	330	270	10	190	160
Mar 07	580	640	470	350	370
Mar 20	720	750	320	970	830
Apr 04	500	490	100	510	520
Apr 17	1,200	1,100	300	1,100	970
May 01	900	1,500	600	1,100	1,100
May 16	1,100	830	1,000	870	820
Jun 05	580	440	320	370	340
Jun 19	610	530	500	630	490
Jul 11	90	40	70	70	80
Jul 25	100	10	190	60	60
Aug 07	11,000	15,000	6,500	29,000	4,300
Aug 21	220	300	600	250	320
Sep 03	40	70	600	70	90
Sep 18	720	710	1,200	730	930
Oct 01	40	40	1,100	110	20
Oct 15	50	<10	90	60	30
Nov 07	2,500	2,300	1,200	1,900	2,000
Nov 21	1,800	1,600	970	1,600	1,800
Dec 04	380	220	300	260	220
Dec 18	230	260	240	200	250

Table 23

Additional Chemical Analysis - 1991

Station	Cl ⁻ (mg/L)	SO ₄ ⁻² (mg/L)	Cr ✓	Metals (ug/L)			Hg	Zn ✓
				Cu ✓	Pb ✓	Mn ✓		
<u>April 17</u>								
1. Lewis Access	22	22	<20	<10	<10	70	<1	<50
2. Upstream DAEC	22	24	<20	<10	<10	90	<1	70
3. Downstream DAEC	21	22	<20	<10	<10	70	<1	<30
4. One-half mile below plant	22	22	<20	<10	<10	60	<1	<30
5. Discharge Canal	53	330	<20	<10	<10	650	<1	70
<u>July 11</u>								
1. Lewis Access	25	28	<20	<50	<10	60	<1	<20
2. Upstream DAEC	23	32	<20	<50	<10	40	<1	<20
3. Downstream DAEC	27	50	<20	<50	<10	50	<1	<20
4. One-half mile below plant	24	42	<20	<50	<10	50	<1	20
5. Discharge Canal	100	500	<20	<50	<10	130	<1	<20

hydride generator for Hg

check with Zn R10 + b2 in lab

Table 24

Benthic Macroinvertebrates Collected from
the Cedar River and Discharge Canal near
Duane Arnold Energy Center
7 July-22 August 1991

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Taxon	Collection Site				
	Lewis Access	U/S DAEC	Disc. Canal	D/S DAEC	½ mi below plant
Arthropoda					
Insecta					
Coleoptera					
Elmidae					
<i>Macronychus glabratus</i>				1	
<i>Stenelmis</i> sp.	1	4		3	2
Diptera					
Chironomidae (larvae)	28	72	11	73	28
Simuliidae					
<i>Simulium</i> sp.	1	1		49	39
Athericidae					
<i>Atherix</i> sp.	1			3	1
Empididae					
<i>Hemerodromia</i> sp.		1			
Ephemeroptera					
Baetidae					
<i>Baetis</i> sp.	34	4		49	78
Caenidae					
<i>Caenis</i> sp.	7	9		2	
Heptageniidae		17			
<i>Heptagenia</i> sp.	13	8		28	62
<i>Stenonema</i> sp.	27	50		74	37
Oligoneuriidae					
<i>Isonychia</i> sp.	22	40		18	77
Tricorythidae					
<i>Tricorythodes</i> sp.	1	3		6	
Odonata					
Coenagrionidae					
<i>Argia</i> sp.		2			
Trichoptera					
Hydropsychidae (Immature larvae)	5	7		158	78
Hydropsychidae (pupae)	54	33		27	58
<i>Hydropsyche bidens</i>	160	35	5	241	441
<i>H. orris</i>	15			15	17
<i>H. simulans</i>	50	29		155	229
<i>Cheumatopsyche</i> sp.	6	5		6	
<i>Potamyia flava</i>	155	41	13	217	6
Mollusca					
Gastropoda					
Physidae			7		1
<i>Physa</i> sp.					
Annelida					
Hirudinea					
Rhynchobdellida			9		
Glossiphoniidae					
Platyhelminthes					
Turbellaria					
Tricladida			5	10	
Planariidae					
Total No. of Organisms	580	361	50	1135	1154
Total No. of Taxa	15	16	6	17	13

DC: Discharge Canal

Note: to convert no. of organisms counted to No./m² multiply by 6.25.

Prepared by UHL Limnology Section

Table 24
(Cont)

Benthic Macroinvertebrates Collected from
the Cedar River and Discharge Canal near
Duane Arnold Energy Center
September 16- October 29, 1991

Taxon	Collection Site				
	Lewis Access	U/S DAEC	Disc. Canal	D/S DAEC	$\frac{1}{2}$ mi below plant
Arthropoda					
Insecta					
Coleoptera					
Elmidae					
<i>Stenelmis</i> sp.	1			2	
Diptera					
Chironomidae (larvae)	437	190	15	278	200
Simuliidae					
<i>Simulium</i> sp.	106	1	2	26	32
Athericidae					
<i>Atherix</i> sp.	48	4	3	23	6
Ephemeroptera					
Baetidae					
<i>Baetis</i> sp.	5	1		1	7
Caenidae					
<i>Caenis</i> sp.	1			2	
Heptageniidae					
<i>Heptagenia</i> sp.	61	15		5	39
<i>Stenonema</i> sp.	54	98		143	117
Oligoneuriidae					
<i>Isonychia</i> sp.	4	2			
Leptophlebiidae					
<i>Leptophlebia</i> sp.				1	
Tricorythidae					
<i>Tricorythodes</i> sp.		2		3	
Megaloptera					
Corydalidae					
<i>Corydalus</i> sp.	2				
Plecoptera (Immature)	6	1		2	6
Pteronarcidae					
<i>Pteronarcys</i> sp.				1	
Taeniopterygidae					
<i>Taeniopteryx</i> sp.	28	10		14	38
Odonata					
Zygoptera					
Coenagrionidae					
<i>Argia</i> sp.		1	1	1	
Calopterygidae					
<i>Hetaerina</i> sp.			1		
Anisoptera					
Gomphidae					
<i>Erpetogomphus</i> sp.				1	
Trichoptera					
Hydropsychidae (Immature larvae)	94	6		7	80
<i>Hydropsyche bidens</i>	415	152	1	69	248
<i>H. orris</i>	63	8		4	20
<i>H. simulans</i>	101	12		12	53
<i>Cheumatopsyche</i> sp.	1	1		3	11
<i>Potamyia flava</i>	640	71	75	171	378

Table 24
(Cont)

Taxon	Collection Site				
	Lewis Access	U/S DAEC	Disc. Canal	D/S DAEC	$\frac{1}{2}$ mi below plant
Mollusca					
Gastropoda					
Physidae					
<i>Physa sp.</i>			16		
Platyhelminthes					
Turbellaria					
Tricladida					
Planariidae			16		
Annelida					
Oligochaeta					
Plesiopora					
Naididae			5	30	
Total No. of Organisms	2116	625	135	850	1296
Total No. of Taxa	17	16	9	20	13

DC: Discharge Canal

Note: to convert no. of organisms counted to No./m² multiply by 6.25.

Prepared by UHL Limnology Section

Table 25

Daily Numbers of Fish Impinged at the Duane Arnold Energy Center
January - December 1991

Day of the Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	10	28	11	4	0	1	0	1	0	0	2
2	0	20	20	0	5	0	2	10	3	0	0	1
3	0	35	20	0	0	0	1	1	0	0	0	0
4	0	35	10	0	2	0	0	0	0	0	0	0
5	0	28	10	0	1	0	0	1	0	0	2	5
6	0	37	17	0	4	0	0	0	2	0	3	4
7	0	21	16	0	0	0	0	1	0	0	3	0
8	1	4	20	3	0	2	0	0	0	0	1	0
9	0	3	12	13	2	0	0	6	0	0	1	3
10	0	5	15	5	0	0	0	1	1	0	6	0
11	0	0	5	3	0	0	0	0	0	0	3	1
12	5	3	8	5	0	0	0	2	2	0	4	2
13	3	1	21	5	0	0	0	8	0	0	1	4
14	0	0	20	2	5	0	1	2	5	0	0	0
15	10	10	13	8	2	0	0	3	0	0	0	0
16	0	8	13	9	0	0	0	3	2	0	2	0
17	0	0	10	6	1	0	2	1	1	0	0	0
18	0	10	15	1	0	0	0	1	0	0	0	0
19	55	5	19	5	0	0	0	0	0	0	4	1
20	12	0	5	8	0	0	1	0	3	0	1	0
21	4	0	30	5	2	0	0	0	0	0	1	0
22	5	10	15	17	2	0	0	0	0	0	5	0
23	12	4	10	3	0	1	0	1	0	0	0	0
24	5	11	12	0	0	0	0	0	0	0	3	0
25	15	4	13	6	0	0	0	0	0	0	0	1
26	2	25	5	0	0	0	0	2	0	0	3	2
27	40	76	12	0	0	0	0	0	0	2	2	1
28	15	85	15	10	0	0	0	0	3	0	0	3
29	0		0	7	0	2	0	0	0	0	0	3
30	0		18	14	0	0	0	0	2	0	3	5
31	2		8		0		0	0		0		0
Total	186	450	435	146	30	5	8	43	25	2	48	37

Annual Total 1,415

Table 26

Comparison of Average Values for Several Parameters at Upstream,
Downstream, and Discharge Canal Locations at the
Duane Arnold Energy Center During Periods of
Station Operation* - 1991

Parameter	Upstream (Sta. 2)	Discharge Canal (Sta. 5)	Mixing Zone (Sta. 3)	Downstream (Sta. 4)
Temperature (°C)	11.1	13.4	11.5 (104)*	11.5 (104)*
Dissolved Solids (mg/L)	323	731	346 (107)	320 (99)
Total Hardness (mg/L)	272	552	289 (106)	283 (104)
Total Phosphate (mg/L)	0.42	0.83	0.44 (105)	0.42 (100)
Nitrate (mg/L as N)	7.5	9.5	7.7 (103)	7.6 (101)
Iron (mg/L)	1.07	1.04	1.13 (106)	1.05 (98)

* Percent of upstream level ()

Table 27

Comparison of Average Yearly Values for Several Parameters in the
Cedar River Upstream from the Duane Arnold Energy Center*
1972-1991

Year	Mean Flow** (cfs)	Turbidity (NTU)	Total PO ₄ (mg/L)	Ammonia (mg/L-N)	Nitrate (mg/L-N)	BOD (mg/L)	Total Hardness (mg/L)
1972	4,418	22	1.10	0.56	0.23	5.7	253
1973	7,900	28	0.84	0.36	1.5	4.0	250
1974	5,580	29	2.10	0.17	4.2	4.7	266
1975	4,206	58	1.08	0.33	2.8	6.5	251
1976	2,082	41	0.25	0.25	2.8	7.3	233
1977	1,393	15	0.33	0.52	2.9	6.5	243
1978	3,709	23	0.26	0.22	4.4	3.3	261
1979	7,041	26	0.29	0.12	6.6	2.5	272
1980	4,523	40	0.34	0.19	5.4	4.3	238
1981	3,610	33	0.77	0.24	6.0	6.5	279
1982	7,252	43	0.56	0.23	8.0	5.1	274
1983	8,912	22	0.25	0.10	8.6	3.3	259
1984	7,325	40	0.32	0.10	5.9	3.9	264
1985	3,250	30	0.31	0.11	4.8	6.7	245
1986	6,375	33	0.26	0.10	6.8	3.7	285
1987	2,625	32	0.24	0.06	5.6	5.8	269
1988	1,546	28	0.30	<0.16	2.8	9.6	246
1989	947	24	0.37	0.30	1.5	10.3	224
1990	5,061	33	0.29	0.20	7.3	4.8	283
1991	8,085	65	0.38	0.20	7.9	4.3	268

* Data from Lewis Access location (Station 1)

**Data from Cedar Rapids gauging station

Table 28

Summary of Relative Loading Values (Average Annual Concentration x Cumulative Runoff) for Several Parameters in the Cedar River Upstream of the Duane Energy Center* 1972-1991.

Year	Mean Flow (cfs)	Cumulative** Runoff (in.)	Turbidity	Relative Loading Values			
				Total PO ₄	Ammonia	Nitrate	BOD
1972	4,418	9.24	203	10.2	5.2	2	53
1973	7,900	16.48	461	13.8	5.9	25	66
1974	5,580	11.64	338	24.4	2.0	49	55
1975	4,206	8.77	509	9.5	2.9	25	57
1976	2,082	4.35	178	1.1	1.1	12	32
1977	1,393	2.91	44	1.0	1.5	8	19
1978	3,709	7.74	178	2.0	1.7	34	26
1979	7,041	14.79	385	4.3	1.8	98	37
1980	4,523	9.45	378	3.2	1.8	51	41
1981	3,610	7.53	248	5.8	1.8	45	49
1982	7,252	15.13	651	8.5	3.5	121	77
1983	8,912	18.00	396	4.5	1.8	155	59
1984	7,325	15.22	609	4.9	1.5	90	59
1985	3,250	6.80	204	2.1	0.8	33	46
1986	6,475	13.11	433	3.4	1.3	89	49
1987	2,625	4.85	155	1.2	0.3	27	28
1988	1,546	2.85	80	0.9	<0.4	8	27
1989	947	1.84	44	0.7	0.6	3	19
1990	5,061	9.34	308	2.7	1.9	68	45
1991	8,085	17.15	1115	6.5	3.4	135	74

* Data from Lewis Access location (Station 1)

**Data from Cedar Rapids gauging station